⑲日本国特許庁(JP)　　⑪特許出願公開

⑫公開特許公報(A)　　昭64-75715

| ⑮Int.Cl.⁴ | 識別記号 | 庁内整理番号 | ㊸公開　昭和64年(1989)3月22日 |
| --- | --- | --- | --- |
| E 02 D 5/50 | | 8404-2D | |
| 5/44 | | A-8404-2D | |
| 5/54 | | 8404-2D | 審査請求　未請求　発明の数 1　(全9頁) |

㊾発明の名称　　ソイルセメント合成杭

㉑特　願　昭62-232536

㉒出　願　昭62(1987)9月18日

⑫発　明　者　千　田　　昌　平　　茨城県竜ケ崎市松葉3-5-10
⑫発　明　者　内　藤　　禎　二　　神奈川県川崎市高津区新作1-4-4
⑫発　明　者　長　岡　　弘　明　　東京都千代田区丸の内1丁目1番2号　日本鋼管株式会社内
⑫発　明　者　岡　本　　　　隆　　東京都千代田区丸の内1丁目1番2号　日本鋼管株式会社内
⑫発　明　者　高　野　　公　寿　　東京都千代田区丸の内1丁目1番2号　日本鋼管株式会社内
⑪出　願　人　日本鋼管株式会社　　東京都千代田区丸の内1丁目1番2号
⑭代　理　人　弁理士　佐々木　宗治　　外1名

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明　細　書

1．発明の名称

ソイルセメント合成杭

2．特許請求の範囲

地盤の地中内に形成され、底端が拡径で所定長さの拡底端拡径部を有するソイルセメント柱と、硬化前のソイルセメント柱内に圧入され、硬化後のソイルセメント柱と一体の底端に所定長さの底端拡大部を有する突起付鋼管杭とからなることを特徴とするソイルセメント合成杭。

3．発明の詳細な説明

〔産業上の利用分野〕

この発明はソイルセメント合成杭、特に地盤に対する杭体強度の向上を図るものに関する。

〔従来の技術〕

一般の杭は引抜き力に対しては、杭自重と周辺摩擦により抵抗する。このため、引抜き力の大きい送電線の鉄塔等の構造物においては、一般の杭は設計が引抜き力で決定され押込み力が余る不経済な設計となることが多い。そこで、引抜き力に抵抗する工法として従来より第11図に示すアースアンカー工法がある。図において、(1)は構造物である鉄塔、(2)は鉄塔(1)の脚柱で一部が地盤(3)に埋設されている。(4)は脚柱(2)に一端が連結されたアンカー用ケーブル、(5)は地盤(3)の地中深くに埋設されたアースアンカー、(6)は杭である。

従来のアースアンカー工法による鉄塔は上記のように構成され、鉄塔(1)が風によって傾倒れした場合、脚柱(2)に引抜き力と押込み力が作用するが、脚柱(2)にはアンカー用ケーブル(4)を介して地中深く埋設されたアースアンカー(5)が連結されているから、引抜き力に対してアースアンカー(5)が大きな抵抗を有し、鉄塔(1)の倒壊を防止している。また、押込み力に対しては杭(6)により抵抗する。

次に、押込み力に対して主眼をおいたものとして、従来より第12図に示す拡底場所打杭がある。この拡底場所打杭は地盤(3)をオーガ等で軟弱層(3a)から支持層(3b)に達するまで掘削し、支持層

(3b)位置に拡底部(7a)を有する杭穴(7)を形成し、杭穴(7)内に鉄筋かご（図示省略）を拡底部(7a)まで建込み、しかる後に、コンクリートを打設して場所打杭(8)を形成してなるものである。(8a)は場所打杭(8)の軸部、(8b)は場所打杭(8)の拡底部である。

かかる従来の拡底場所打杭は上記のように構成され、場所打杭(8)に引抜き力と押込み力が同様に作用するが、場所打杭(8)の底端は拡底部(8b)として形成されており支持面積が大きく、圧縮力に対する耐力は大きいから、押込み力に対して大きな抵抗を有する。

〔発明が解決しようとする問題点〕

上記のような従来のアースアンカー工法による例えば鉄塔では、押込み力が作用した時、アンカー用ケーブル(4)が座屈してしまい押込み力に対して抵抗がきわめて弱く、押込み力にも抵抗するためには押込み力に抵抗する工法を併用する必要があるという問題点があった。

また、従来の拡底場所打杭では、引抜き力に対して抵抗する引張耐力は鉄筋量に依存するが、鉄筋量が多いとコンクリートの打設に悪影響を与えることから、一般に拡底部近くでは軸部(8a)の第12図のa－a横断面の配筋量0.4～0.8%となり、しかも場所打杭(8)の拡底部(8b)における地盤(3)の支持層(3a)面の周面摩擦強度が充分な場合の場所打杭(8)の引張り耐力は軸部(8a)の引張耐力と等しく、拡底柱部(8b)があっても場所打杭(8)の引抜き力に対する抵抗を大きくとることができないという問題点があった。

この発明はかかる問題点を解決するためになされたもので、引抜き力及び押込み力に対しても充分抵抗できるソイルセメント合成杭を得ることを目的としている。

〔問題点を解決するための手段〕

この発明に係るソイルセメント合成杭は、地盤の地中内に形成され、底端が拡径で所定長さの杭底端拡径部を有するソイルセメント柱と、硬化前のソイルセメント柱内に圧入され、硬化後のソイルセメント柱と一体の底端に所定長さの底端拡大部を有する突起付鋼管杭とから構成したものである。

〔作用〕

この発明においては地盤の地中内に形成され、底端が拡径で所定長さの杭底端拡径部を有するソイルセメント柱と、硬化前のソイルセメント柱内に圧入され、硬化後のソイルセメント柱と一体の底端に所定長さの底端拡大部を有する突起付鋼管杭とからなるソイルセメント合成杭とすることにより、鉄筋コンクリートによる場所打杭に比べて鋼管杭を内蔵しているため、ソイルセメント合成杭の引張り耐力は大きくなり、しかもソイルセメント柱の底端に杭底端拡径部を設けたことにより、地盤の支持層とソイルセメント柱間の周面面積が増大し、周面摩擦による支持力を増大させている。この支持力の増大に対応させて突起付鋼管杭の底端に底端拡大部を設けることにより、ソイルセメント柱と鋼管杭間の周面摩擦強度を増大させているから、引張り耐力が大きくなったとしても、突起付鋼管杭がソイルセメント柱から抜けることはなくなる。

〔実施例〕

第1図はこの発明の一実施例を示す断面図、第2図(a)乃至(d)はソイルセメント合成杭の施工工程を示す断面図、第3図は拡翼ビットと拡翼ビットが取り付けられた突起付鋼管杭を示す断面図、第4図は突起付鋼管杭の本体部と底端拡大部を示す平面図である。

図において、(10)は地盤、(11)は地盤(10)の軟弱層、(12)は地盤(10)の支持層、(13)は軟弱層(11)と支持層(12)に形成されたソイルセメント柱、(13a)はソイルセメント柱(13)の杭一般部、(13b)はソイルセメント柱(13)の所定の長さ$d_2$を有する杭底端拡径部、(14)はソイルセメント柱(13)内に圧入され、埋込まれた突起付鋼管杭、(14a)は鋼管杭(14)の本体部、(14b)は鋼管杭(13)の底端に形成された本体部(14a)より拡径で所定長さ$d_1$を有する底端拡大管部、(15)は鋼管杭(14)内に挿入され、先端に拡翼ビット(16)を有する掘削管、(15a)は拡翼ビット(16)に設けられ

た刃、(17)は攪拌ロッドである。

この実施例のソイルセメント合成杭は第2図(a)乃至(d)に示すように施工される。

地盤(10)上の所定の穿孔位置に、拡翼ビット(16)を有する掘削管(15)を内部に挿通させた突起付鋼管杭(14)を立設し、突起付鋼管杭(14)を運動力等で地盤(10)にねじ込むと共に掘削管(15)を回転させて拡翼ビット(16)により穿孔しながら、攪拌ロッド(17)の先端からセメント系硬化剤からなるセメントミルク等の注入材を出して、ソイルセメント柱(13)を形成していく。そしてソイルセメント柱(13)が地盤(10)の軟弱層(11)の所定深さに達したら、拡翼ビット(15)を拡げて拡大掘りを行い、支持層(12)まで掘り進み、底端が拡径で所定長さの杭底端拡径部(13b)を有するソイルセメント柱(13)を形成する。このとき、ソイルセメント柱(13)内には、底端に拡径の底端拡大管部(14b)を有する突起付鋼管杭(14)も挿入されている。なお、ソイルセメント柱(13)の硬化前に攪拌ロッド(16)及び掘削管(15)を引き抜いておく。

ソイルセメントが硬化すると、ソイルセメント柱(13)と突起付鋼管杭(14)とが一体となり、底端に円柱状拡径部(18b)を有するソイルセメント合成杭(18)の形成が完了する。(18a)はソイルセメント合成杭(18)の杭一般部である。

この実施例では、ソイルセメント柱(13)の形成と同時に突起付鋼管杭(14)も挿入されてソイルセメント合成杭(18)が形成されるが、予めオーガ等によりソイルセメント柱(13)だけを形成し、ソイルセメント硬化前に突起付鋼管杭(14)を圧入してソイルセメント合成杭(18)を形成することもできる。

第6図は突起付鋼管杭の変形例を示す断面図、第7図は第6図に示す突起付鋼管杭の変形例の平面図である。この変形例は、突起付鋼管杭(24)の本体部(24a)の底端に複数の突起付板が放射状に突出した底端拡大板部(24b)を有するもので、第3図及び第4図に示す突起付鋼管杭(14)と同様に機能する。

上記のように構成されたソイルセメント合成杭においては、圧縮耐力の強いソイルセメント柱(13)と引張耐力の強い突起付鋼管杭(14)とでソイルセメント合成杭(18)が形成されているから、杭体に対する押込み力の抵抗は勿論、引抜き力に対する抵抗が、従来の拡底場所打ち杭に比べて格段に向上した。

また、ソイルセメント合成杭(18)の引張耐力を増大させた場合、ソイルセメント柱(13)と突起付鋼管杭(14)間の付着強度が小さければ、引抜き力に対してソイルセメント合成杭(18)全体が地盤(10)から抜ける前に突起付鋼管杭(14)がソイルセメント柱(13)から抜けてしまうおそれがある。しかし、地盤(10)の軟弱層(11)と支持層(12)に形成されたソイルセメント柱(13)がその底端に拡径で所定長さの杭底端拡径部(13b)を有し、その杭底端拡径部(13b)内に突起付鋼管杭(14)の所定長さの底端拡大管部(14b)が位置するから、ソイルセメント柱(13)の底端に杭底端拡径部(13b)を設け、底端で断面面積が杭一般部(13a)より増大したことによって地盤(10)の支持層(12)とソイルセメント柱(13)間の周面摩擦強度が増大したとしても、これに対応して突起付鋼管杭(14)の底端に底端拡大管部(14b)或いは底端拡大板部(24b)を設け、底端での断面面積を増大させることによってソイルセメント柱(13)と突起付鋼管杭(14)間の付着力を増大させているから、引張耐力が大きくなったとしても突起付鋼管杭(14)がソイルセメント柱(13)から抜けることはなくなる。従って杭体に対する押込み力は勿論、引抜き力に対してもソイルセメント合成杭(18)は大きな抵抗を有することとなる。なお、鋼管杭を突起付鋼管杭(14)としたのは、本体部(14a)及び底端拡大部(14b)の双方で鋼管とソイルセメントの付着強度を高めるためである。

次に、この実施例のソイルセメント合成杭における杭径の関係について具体的に説明する。

ソイルセメント柱(13)の杭一般部の径：$D so_1$

突起付鋼管杭(14)の本体部の径：$D st_1$

ソイルセメント柱(13)の底端拡径部の径：$D so_2$

突起付鋼管杭(14)の底端拡大管部の径：$Dst_2$とすると、次の条件を満足することがまず必要である。

$$Dso_1 > Dst_1 \quad \text{— (a)}$$

$$Dso_2 > Dso_1 \quad \text{— (b)}$$

次に、第8図に示すようにソイルセメント合成杭の杭一般部におけるソイルセメント柱(13)と軟弱層(11)間の単位面積当りの周面摩擦強度を$S_1$、ソイルセメント柱(13)と突起付鋼管杭(14)の単位面積当りの周面摩擦強度を$S_2$とした時、$Dso_1$と$Dst_1$は、

$$S_2 \geqq S_1 (Dst_1 / Dso_1) \quad \text{— (1)}$$

の関係を満足するようにソイルセメントの配合をきめる。このような配合とすることにより、ソイルセメント柱(13)と地盤(10)間をすべらせ、ここに周面摩擦力を得る。

ところで、いま、軟弱地盤の一軸圧縮強度を$Qu = 1$ kg/cm²、周辺のソイルセメントの一軸圧縮強度を$Qu = 5$ kg/cm²とすると、この時のソイルセメント柱(13)と軟弱層(11)間の単位面積当りの周面摩擦強度$S_1$は$S_1 = Qu / 2 = 0.5$ kg/cm²。

また、突起付鋼管杭(14)とソイルセメント柱(13)間の単位面積当りの周面摩擦強度$S_2$は、実験結果から$S_2 \fallingdotseq 0.4Qu \fallingdotseq 0.4 \times 5$ kg/cm² $\fallingdotseq 2$ kg/cm²が期待できる。上記式(1)の関係から、ソイルセメントの一軸圧縮強度が$Qu = 5$ kg/cm²となった場合、ソイルセメント柱(13)の杭一般部(13a)の径$Dso_1$と突起付鋼管杭(14)の本体部(14a)の径の比は、4：1とすることが可能となる。

次に、ソイルセメント合成杭の円柱状拡径部について述べる。

突起付鋼管杭(14)の底端拡大管部(14b)の径$Dst_2$は、

$$Dst_2 \leqq Dso_1 \text{ とする} \quad \cdots \text{(c)}$$

上述式(c)の条件を満足することにより、突起付鋼管杭(14)の底端拡大管部(14b)の挿入が可能となる。

次に、ソイルセメント柱(13)の杭底端拡径部(13b)の径$Dso_2$は次のように決定する。

まず、引抜き力の作用した場合を考える。

いま、第9図に示すようにソイルセメント柱(13)の杭底端拡径部(13b)と支持層(12)間の単位面積当りの周面摩擦強度を$S_3$、ソイルセメント柱(13)の杭底端拡径部(13b)と突起付鋼管杭(14)の底端拡大管部(14b)又は先端拡大板部(24b)間の単位面積当りの周面摩擦強度を$S_4$、ソイルセメント柱(13)の杭底端拡径部(13b)と突起付鋼管杭(14)の先端拡大板部(24b)の付着面積を$A_4$、支圧力を$Fb_1$とした時、ソイルセメント柱(13)の杭底端拡径部(8b)の径$Dso_2$は次のように決定する。

$$\pi \times Dso_2 \times S_3 \times d_2 + Fb_1 \leqq A_4 \times S_4 \quad \cdots (2)$$

$Fb_1$はソイルセメント部の破壊と上部の土が破壊する場合が考えられるが、$Fb_1$は第9図に示すように剪断破壊するものとして、次の式で表わせる。

$$Fb_1 = \frac{(Qu \times 2) \times (Dso_2 - Dso_1)}{2} \times \frac{\sqrt{2} \times \pi \times (Dso_2 + Dso_1)}{2} \quad \cdots (3)$$

いま、ソイルセメント合成杭(18)の支持層(12)となる層は砂または砂礫である。このため、ソイルセメント柱(13)の杭底端拡径部(13b)においては、コンクリートモルタルとなるソイルセメントの強度は大きく一軸圧縮強度$Qu \fallingdotseq 100$ kg/cm²程度以上の強度が期待できる。

ここで、$Qu \fallingdotseq 100$ kg/cm²、$Dso_1 = 1.0$m、突起付鋼管杭(14)の底端拡大管部(14b)の長さ$d_1$を2.0m、ソイルセメント柱(13)の杭底端拡径部(13b)の長さ$d_2$を2.5m、$S_3$は道路橋示方書から支持層(12)が砂質土の場合、
$0.5N \leqq 20$t/m²とすると、$S_3 = 20$t/m²、$S_4$は実験結果から$S_4 \fallingdotseq 0.4 \times Qu = 400$t/m²、$A_4$が突起付鋼管杭(14)の底端拡大管部(14b)のとき、$Dso_1 = 1.0$m、$d_1 = 2.0$mとすると、

$$A_4 = \pi \times Dso_1 \times d_1 = 3.14 \times 1.0\text{m} \times 2.0 = 6.28\text{m}^2$$

これらの値を上記(2)式に代入し、更に(3)式に

代入して、

$Dst_2 = Dso_1 \cdot S_2 / S_1$ とすると

$Dst_2 \fallingdotseq 2.2$mとなる。

次に、押込み力の作用した場合を考える。

いま、第10図に示すようにソイルセメント柱(13)の抗底端拡径部(13b)と支持層(12)間の単位面積当りの周面摩擦強度を$S_3$、ソイルセメント柱(13)の抗底端拡径部(13b)と突起付鋼管杭(14)の底端拡大管部(14b)又は底端拡大板部(24b)の単位面積当りの周面摩擦強度を$S_4$、ソイルセメント柱(13)の抗底端拡径部(13b)と突起付鋼管杭(14)の底端拡大管部(14b)又は底端拡大板部(24b)の付着面積を$A_4$、支圧強度を$fb_2$とした時、ソイルセメント柱(13)の底端拡径部(13b)の径$Dso_2$は次にように決定する。

$$\pi \times Dso_2 \times S_3 \times d_2 + fb_2 \times \pi \times (Dso_2/2)^2 \leqq A_4 \times S_4 \quad \cdots(4)$$

いま、ソイルセメント合成杭(10)の支持層(12)となる層は、砂または砂礫である。このため、ソイルセメント柱(13)の抗底端拡径部(13b)においては、コンクリートモルタルとなるソイルセメントの強度は大きく、一軸圧縮強度Quは約1000kg/cm²程度の強度が期待できる。

ここで、$Qu \fallingdotseq 100$ kg/cm²、$Dso_1 = 1.0$m、$d_1 = 2.0$m、$d_2 = 2.5$m、

$fb_2$は道路橋示方書から、支持層(12)が砂礫層の場合、$fb_2 = 20$t/m²

$S_3$は道路橋示方書から、$0.5N \leqq 20$t/m²とすると$S_3 = 20$t/m²、

$S_4$は実験結果から$S_4 \fallingdotseq 0.4 \times Qu \fallingdotseq 400$t/m²

$A_4$が突起付鋼管杭(14)の底端拡大管部(14b)のとき、

$Dso_1 = 1.0$m、$d_1 = 2.0$mとすると、

$$A_4 = \pi \times Dso_1 \times d_1 = 3.14 \times 1.0 \times 2.0 = 6.28\text{m}^2$$

これらの値を上記(4)式に代入して、

$Dst_2 \leqq Dso_1$ とすると、

$Dso_2 \fallingdotseq 2.1$mとなる。

従って、ソイルセメント柱(13)の抗底端拡径部(14a)の径$Dso_2$は引抜き力により決定される場合の$Dso_2$は約2.2mとなり、押込み力により決定される場合の$Dso_2$は約2.1mとなる。

最後にこの発明のソイルセメント合成杭と従来の拡底場所打杭の引張耐力の比較をしてみる。

従来の拡底場所打杭について、場所打杭(8)の軸部(8a)の軸径を1000mm、軸部(8a)の第12図のa－a線断面の配筋量を0.8%とした場合における軸部の引張耐力を計算すると、

$$\text{鉄筋量}\quad \frac{100^2}{4}\pi \times \frac{0.8}{100} = 62.83\ \text{cm}^2$$

鉄筋の引張耐力を3000kg/cm²とすると、

軸部の引張耐力は$62.83 \times 3000 \fallingdotseq 188.5$ton

ここで、軸部の引張耐力を鉄筋の引張耐力としているのは場所打杭(8)が鉄筋コンクリートの場合、コンクリートは引張耐力を期待できないから鉄筋のみで負担するためである。

次にこの発明のソイルセメント合成杭について、ソイルセメント柱(13)の抗一般部(13a)の軸径を1000mm、突起付鋼管杭(14)の本体部(14a)の口径を800mm、厚さを19mmとすると、

鋼管断面積　466.2 cm²

鋼管の引張耐力　2400kg/cm²とすると、

突起付鋼管杭(14)の本体部(14a)の引張耐力は

$466.2 \times 2400 \fallingdotseq 1118.9$ton である。

従って、同軸径の拡底場所打杭の約6倍となる。それ故、従来例に比べてこの発明のソイルセメント合成杭では、引抜き力に対して、突起付鋼管杭の底端に底端拡大部を設けて、ソイルセメント柱と鋼管杭間の付着強度を大きくすることによって大きな抵抗をもたせることが可能となった。

【発明の効果】

この発明は以上説明したとおり、地盤の地中内に形成され、底端が拡径で所定長さの抗底端拡径部を有するソイルセメント柱と、硬化前のソイルセメント柱内に圧入され、硬化後のソイルセメント柱と一体の底端に所定長さの底端拡大部を有する突起付鋼管杭とからなるソイルセメント合成杭としているので、施工の際にソイルセメント工法をとることとなるため、低騒音、低振動となり排土が少なくなり、また鋼管杭としているために従

来の拡底場所打杭に比べて引張耐力が向上し、引張耐力の向上に伴い、突起付鋼管杭の底端に底端拡大部を設け、底端での周面面積を増大させてソイルセメント柱と鋼管杭間の付着強度を増大させているから、突起付鋼管杭がソイルセメント柱から抜けることなく引抜き力に対して大きな抵抗を有するという効果がある。

また、突起付鋼管杭としているので、ソイルセメント柱に対して付着力が高まり、引抜き力及び押込み力に対しても抵抗が大きくなるという効果もある。

更に、ソイルセメント柱の杭底端拡径部及び突起付鋼管杭の底端拡大部の径または長さを引抜き力及び押込み力の大きさによって変化させることによってそれぞれの荷重に対して最適な杭の施工が可能となり、経済的な杭が施工できるという効果もある。

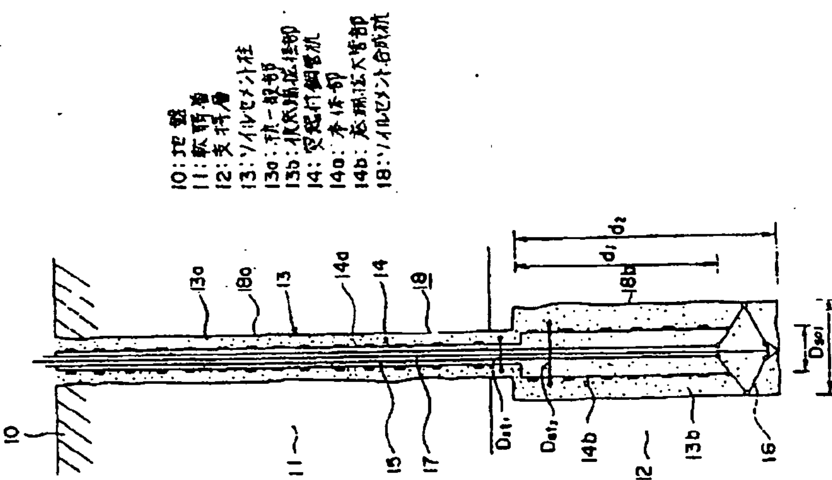
4．図面の簡単な説明

第1図はこの発明の一実施例を示す断面図、第2図(a)乃至(d)はソイルセメント合成杭の施工工程を示す断面図、第3図は拡翼ビットと拡翼ビットが取り付けられた突起付鋼管杭を示す断面図、第4図は突起付鋼管杭の本体部と先端拡大管部を示す断面図、第5図は同突起付鋼管杭の本体部と先端拡大管部を示す平面図、第6図は突起付鋼管杭の変形例を示す断面図、第7図は第6図に示す突起付鋼管杭の変形例の平面図、第8図は軟弱層の地盤支持力を確保するための説明図、第9図は引抜き力に対する支持層の地盤支持力を確保するための説明図、第10図は押込み力に対する支持層の地盤支持力を確保するするための説明図、第11図は従来のアースアンカー工法による鉄塔を示す説明図、第12図は従来の拡底場所打杭を示す断面図である。

(10)は地盤、(11)は軟弱層、(12)は支持層、(13)はソイルセメント柱、(13a)は杭一般部、(13b)は杭底端拡径部、(14)は突起付鋼管杭、(14a)は本体部、(14b)は底端拡大管部、(18)はソイルセメント合成杭。

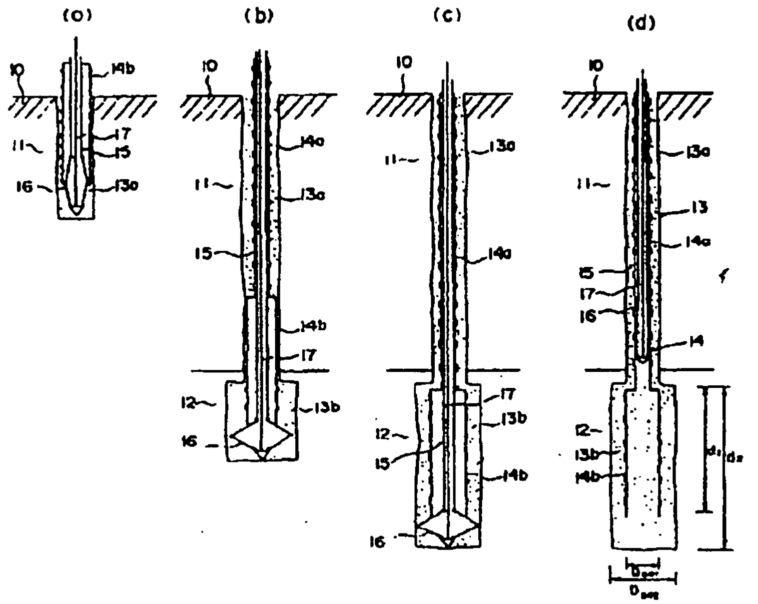
代理人　弁理士　佐々木宗治

第1図




代理人 弁理士 佐々木宗治

第 2 図

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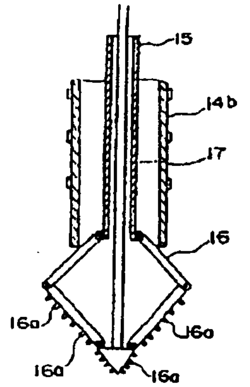


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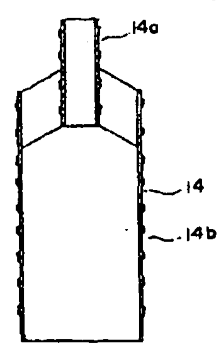


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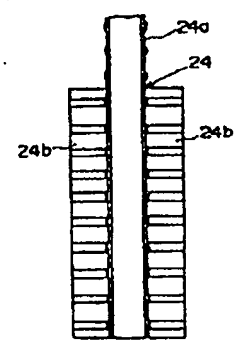


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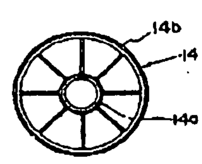


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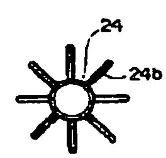
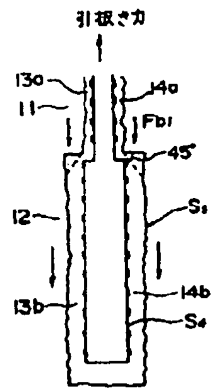
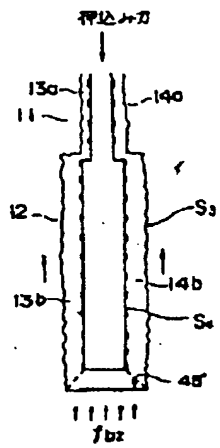


第 8 図

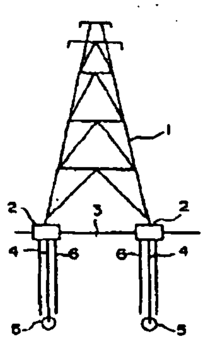

第 9 図



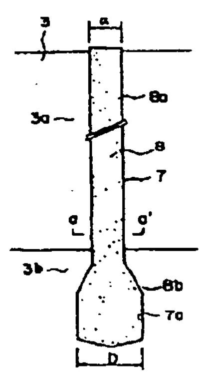

第 10 図




第 11 図




第 12 図



第1頁の続き

⑫発 明 者　広 瀬　鉄 蔵　東京都千代田区丸の内1丁目1番2号　日本鋼管株式会社内

CLIPPEDIMAGE= JP401075715A
PAT-NO: JP401075715A
DOCUMENT-IDENTIFIER: JP 01075715 A
TITLE: SOIL CEMENT COMPOSITE PILE

PUBN-DATE: March 22, 1989

INVENTOR-INFORMATION:
NAME
SENDA, SHOHEI
NAITO, TEIJI
NAGAOKA, HIROAKI
OKAMOTO, TAKASHI
TAKANO, KIMIHISA
HIROSE, TETSUZO

ASSIGNEE-INFORMATION:

| NAME | COUNTRY |
|---|---|
| NKK CORP | N/A |

APPL-NO: JP62232536
APPL-DATE: September 18, 1987

INT-CL_(IPC): E02D005/50; E02D005/44 ; E02D005/54
US-CL-CURRENT: 405/232

ABSTRACT:
PURPOSE: To raise the drawing and penetrating forces of soil cement composite piles by a method in which a steel tubular pile having a projection with an expanded bottom end is penetrated into a soil cement column with an expanded bottom end in the ground before it hardens.

CONSTITUTION: A steel tubular pile 14 with a projection on the ground 10 is penetrated into the ground 10. An excavating tube 15 is turned and cement milk is injected from the tip of a stirring blade rod 17 while excavating the ground with a expandible blade bit 16 to form a soil cement column 13. When the column 13 reaches a given depth into soft ground layer 11, an expandible blade bit 15 is expanded to excavate an expanded-diameter pit down to the bearing layer 12 in order to form the column 13 with an expanded diameter portion 13b.

(19) Japan Patent Office (JP)
(12) Japanese Unexamined Patent Application Publication (A)
(11) Japanese Unexamined Patent Application Publication Number S64-75715
(43) Publication Date: March 22, 1989

| (51) Int. Cl.$^4$ | Identification No. | Internal Filing No. |
|---|---|---|
| E02D 5/50 | | 8404-2D |
| 5/44 | | A-8404-2D |
| 5/54 | | 8404-2D |

Application for Inspection: Not yet filed
Number of Inventions: 1 (total 9 pages)

(54) Title of the Invention: SOIL CEMENT COMPOSITE PILE

(21) Japanese Patent Application S62-232536

(22) Application Filed: September 18, 1987

(72) Inventor: Shouhei Chida 3-5-10 Matsuba, Ryuugasaki-shi, Ibaraki-ken

(72) Inventor: Sadaji Naitou 1-4-4 Shinsaku, Takatsu-ku, Kawasaki-shi, Kanagawa-ken

(72) Inventor: Hiroaki Nagaoka c/o NKK Corporation 1-1-2 Marunouchi, Chiyoda-ku, Tokyo

(72) Inventor: Takashi Okamoto c/o NKK Corporation 1-1-2 Marunouchi, Chiyoda-ku, Tokyo

(72) Inventor: Kimitoshi Takano c/o NKK Corporation 1-1-2 Marunouchi, Chiyoda-ku, Tokyo

(71) Applicant: NKK Corporation 1-1-2 Marunouchi, Chiyoda-ku, Tokyo

(74) Agent: Patent Attorney Muneharu Sasaki and one other individual

Continued on final page

## Specifications

1. Title of the Invention

Soil Cement Composite Pile

2. Scope of the Patent Claims

A soil cement composite pile that is characterized as comprising:

(a) a soil cement column that is formed under the foundation, the bottom end having an expanded diameter, and has a pile bottom end expanded diameter region of prescribed length; and

(b) a projection steel pipe pile that is pressed into the soil cement column before hardening, and has a bottom end enlarged region of prescribed length on the bottom end [sic] that is united with the soil cement column after hardening.

3. Detailed Description of the Invention

(Field of Industrial Utilization)
This invention is related to a soil cement composite pile; in particular, a soil cement composite pile that improves pile strength with respect to the foundation.

(Prior Art)
Common piles oppose pulling force with their own weight and peripheral friction. Therefore, in structures such as steel towers with power transmission wires that have a large pulling force, the pulling force determines the designs of common piles, and they often result in uneconomical designs in which there is an excess pressing force. Thereby, as a method of construction that opposes pulling force, conventionally there has been the earth anchor construction method shown in Figure 11. In the figure, (1) is the structure, the steel tower, and (2) are pier studs of steel tower (1), portions of which are buried in foundation (3). (4) is an anchor cable, one end of which is connected to pier stud (2), (5) is the earth anchor that is buried deep within foundation (3), and (6) is the pile.

Steel towers created through the conventional earth anchor construction method are configured as described above, and if steel tower (1) sways laterally due to the wind, pulling forces and pressing forces act upon pier studs (2), but because earth anchors (5) that are buried deep within the earth are connected to pier studs (2) with anchor cables (4), the earth anchors (5) have large resistance with respect to pulling force and they prevent the collapse of steel tower (1). Moreover, pressing force is opposed by pile (6).

Next, as a focus with respect to pressing force, conventionally there has been the expanded bottom cast-in-place pile shown in Figure 12. This expanded bottom cast-in-place pile is constructed by excavating foundation (3) with an auger from soft layer (3a) to support layer (3b), forming post hole (7) that has expanded bottom region (7a) on the support layer (3b) position, building a reinforced cage (omitted from the figure) inside post hole (7) until expanded bottom region (7a), and thereafter casting concrete to form cast-in-place pile (8). (8a) is the shank of cast-in-place pile (8), and (8b) is the expanded bottom region of cast-in-place pile (8).

This conventional expanded bottom cast-in-place pile is configured as described above. Pulling forces and pressing forces act upon cast-in-place pile (8) in the same way, but the bottom end of cast-in-place pile (8) is formed as the expanded bottom region (8b), the support area is large, and resistance with respect to compressive force is large, so it has large resistance with respect to pressing force. [sic]

(Problems Addressed by the Invention)
With steel towers, for example, that are created through conventional earth anchor construction methods such as that described above, there was the problem in which, when the pressing force acts upon the tower, the anchor cables (4) buckle and the resistance with respect to pressing force becomes extremely weak, so in order to resist pressing force as well, it is necessary to simultaneously use a construction method that resists pressing force.

Moreover, with the conventional expanded bottom cast-in-place pile, the tensile resistance that opposes the pulling force depends on the quantity of reinforcement bars, but because concrete casting is adversely affected when the quantity of reinforcement bars is large, there was the problem in which the bar arrangement quantity of the a-a line cross section of Figure 12 of shank (8a) becomes 0.4 to 0.8%, and furthermore, the tensile resistance of cast-in-place pile (8) is equal to the tensile resistance of shank (8a) if the peripheral frictional strength between support layers (3a) of foundation (3) in the expanded bottom region (8b) of cast-in-place pile (8) is sufficient, and it is not possible to make the resistance large with respect to the pulling force of cast-in-place pile (8) even if there exists expanded bottom column region (8b).

This invention was created in order to solve these problems, so its object is to obtain a soil cement composite pile that can sufficiently resist with respect to both pulling force and pressing force.

(Means for Solving the Problems)
The soil cement composite pile of this invention comprises (a) a soil cement column that is formed under the foundation, the bottom end having an expanded diameter, and has a pile bottom end expanded diameter region of prescribed length, and (b) a projection steel pipe pile that is pressed into the soil cement column before hardening, and has a bottom end enlarged region of prescribed length on the bottom end that is united with the soil cement column after hardening.

(Operation)
In this invention, by creating a soil cement composite pile that comprises (a) a soil cement column that is formed under the foundation, the bottom end having an expanded diameter, and has a pile bottom end expanded diameter region of prescribed length, and (b) a projection steel pipe pile that is pressed into the soil cement column before hardening, and has a bottom end enlarged region of prescribed length on the bottom end that is united with the soil cement column after hardening, the soil cement composite pile tensile resistance becomes large in comparison to cast-in-place piles made of reinforced concrete due to the fact is has a built-in steel pipe pile. Furthermore, by establishing a pile bottom end expanded diameter region on the bottom end of the soil cement column, the periphery area between the support layer of the foundation and the soil cement column is increased, and the bearing capacity due to peripheral friction is increased. By establishing a bottom end enlarged region on the bottom end of the projection steel pipe pile in accordance with this bearing capacity increase, the peripheral frictional strength between the soil cement column and the steel pipe pile is increased, so even if the tensile resistance were to become large, the projection steel pipe pile would not drop out of the soil cement column.

(Examples of Embodiment)
Figure 1 is a cross sectional diagram that shows one example of embodiment of this invention; Figures 2 (a) through (d) are cross sectional diagrams that show the construction processes of the soil cement composite pile; Figure 3 is a cross sectional diagram that shows a projection steel pipe pile to which expansion wing bits are mounted; and Figure 4 is a plan view that shows the main body region and the bottom end enlarged region of the projection steel pipe pile.

In the figures, (10) is the foundation, (11) is the soft layer of foundation (10), (12) is the support layer of foundation (10), (13) is the soil cement column formed on the soft layer (11) and the support layer (12), (13a) is pile general region of soil cement column (13), (13b) is the pile bottom end expanded diameter region that has prescribed length $d_2$, (14) is the projection steel pipe pile that is pressed into soil cement column (13) and built up, (14a) is the main body region of steel pipe pile (14), (14b) is the bottom end enlarged pipe region that has a larger diameter than the main unit (14a) formed on the bottom end of steel pipe pile (13) and has prescribed length $d_1$, (15) is the excavating pipe that is inserted into steel pipe pile (14) and has expansion wing bit (16) on its tip, (16a) is the edge that is established on expansion wing bit (16), and (17) is a stirring rod.

The soil cement composite pile of this embodiment is constructed as shown in Figures 2 (a) through (d).

Projection steel pipe pile (14), which passes excavating pipe (15) that has expansion wing bit (16) into the interior, is established at a prescribed borehole position on foundation (10). Projection steel pipe pile (14) is screwed into foundation (10) using electromotive power, and while rotating excavating pipe (15) and boring with expansion wing bit (16), an infusing material such as cement milk made from a cement-family hardening agent is extracted from the tip of stirring rod (17), and soil cement column (13) is formed. Then, when soil cement column (13) reaches a prescribed depth in the soft layer (11) of foundation (10), expansion wing bit (15) is expanded and enlargement boring is performed and continued until support layer (12), and soil cement column (13), whose bottom end has an expanded diameter and has a pile bottom end expanded diameter region (13b) of prescribed length, is formed. At this time, projection steel pipe pile (14), which has bottom end enlarged pipe region (14b) with an expanded diameter on the bottom end, is also inserted into soil cement column (13). Furthermore, stirring rod (16) [sic] and excavating pipe (15) are drawn out prior to the hardening of soil cement column (13).

When the soil cement hardens, soil cement column (13) and projection steel pipe pile (14) become unified, and the formation of soil cement composite pile (18), which has cylindrical expanded diameter region (18b) on its bottom end, is completed. (18a) is the pile general region of soil cement composite pile (18).

In this example of embodiment, projection steel pipe pile (14) is also inserted simultaneously with the formation of soil cement column (13) to form soil cement composite pile (18), but it is also possible to form soil cement composite pile (18) by forming cement column (13) with an auger in advance soil and pressing projection steel pipe pile (14) prior to soil cement hardening.

Figure 6 is a cross sectional diagram that shows an example of variation of the projection steel pipe pile, and Figure 7 is a plan view of the example of variation of the projection steel pipe pile shown in Figure 6. This variation has on the bottom end of the main body region (24a) of projection steel pipe pile (24) bottom end expanded plate regions (24b) in which a plurality of projection plates project radially, so it functions in the same manner as projection steel pipe pile (14) shown in Figure 3 and Figure 4.

In the soil cement composite pile configured as described above, soil cement composite pile (18) is formed with soil cement column (13) that has strong compression resistance and projection steel pipe pile (14) that has strong tensile resistance, so not only the pressing force resistance with respect to the pile, but the resistance with respect to pulling force is also markedly improved in comparison to the conventional expanded bottom cast-in-place pile.

Moreover, if the tensile resistance of soil cement composite pile (18) is increased, if the bond strength between soil cement column (13) and joint steel pipe pile (14) is low, then there is the danger that projection steel pipe pile (14) will escape from soil cement column (13) due to pulling force before the entire soil cement composite pile (18) escapes from foundation (10). However, soil cement column (13) that is formed on the soft layer (11) and the support layer (12) of foundation (10) has on its bottom end a pile bottom end expanded diameter region (13b) with an expanded diameter and prescribed length, and bottom end enlarged pipe region (14b) with prescribed length on projection steel pipe pile (14) is located within this pile bottom end expanded diameter region (13b). Therefore, pile bottom end expanded diameter region (13b) is established on the bottom end of soil cement column (13), and even if the peripheral frictional strength between the support layer (12) of foundation (10) and soil cement column (13) increases because the periphery area at the bottom end becomes greater than the pile general region (13a), either bottom end enlarged pipe region (14b) or bottom end enlarged plate region (24b) is established on the bottom end of projection steel pipe pile (14) in response to this. The bond strength between soil cement column (13) and projection steel pipe pile (14) is increased by increasing the periphery area at the bottom end, so even if the tensile resistance becomes large, projection steel pipe pile (14) will not escape from soil cement column (13). Accordingly, in addition to pressing force with respect to the pile, of course, soil cement composite pile (18) will have large resistance with respect to pulling force as well. Moreover, the reason that the projection steel pipe pile (14) was used as the steel pipe pile was to increase the soil cement bond strength with the steel pipe in both the main body region (14a) and the bottom end enlarged region (14b).

Next, the pile diameter relationship in the soil cement composite pile of this example of embodiment will be described in detail.

If the diameter of the pile general region of soil cement column (13) = $Dso_1$,
the diameter of the main body region of projection steel pipe pile (14) = $Dst_1$,
the diameter of the bottom end expanded diameter region of soil cement column (13) = $Dso_2$, and
the diameter of the bottom end enlarged pipe region of projection steel pipe pile (14) = $Dst_2$, then it is first necessary to satisfy the following conditions:

$Dso_1 > Dst_1$ ... (a)
$Dso_2 > Dso_1$ ... (b)

Next, as shown in Figure 8, when the peripheral frictional strength per unit area between soil cement column (13) and the soft layer (11) in the pile general region of the soil cement composite pile is taken to be $S_1$, and the peripheral frictional strength per unit area of soil cement column (13) and projection steel pipe pile (14) is taken to be $S_2$, the soil cement combination is decided such that $Dso_1$ and $Dst_1$ satisfy the relation:

$$S_2 \geq S_1 \quad (Dst_1/Dso_1) \qquad \ldots (1)$$

By taking such a combination, soil cement column (13) and foundation (10) are made to mutually slide and peripheral frictional force is obtained.

Incidentally, if at this time the uniaxial compressive strength of the soft foundation is taken to be Qu = 1 kg/cm$^2$, and the uniaxial compressive strength of the peripheral soil cement is taken to be Qu = 5 kg/cm$^2$, then the peripheral frictional strength $S_1$ per unit area between soil cement column (13) and soft layer (11) at this time becomes $S_1$ = Qu/2 = 0.5 kg/cm$^2$.

Moreover, from experimental results, the peripheral frictional strength $S_2$ per unit area between projection steel pipe pile (14) and soil cement column (13) can be expected to be $S_2 \fallingdotseq 0.4Qu \fallingdotseq 0.4 \times 5$ kg/cm$^2 \fallingdotseq$ 2 kg/cm$^2$. From the relation of formula (1) described above, when the uniaxial compressive strength of the soil cement becomes Qu = 5 kg/cm$^2$, it is possible to make 4:1 the ratio of the diameter $Dso_1$ of pile general region (13a) of soil cement column (13) to the diameter of main body region (14a) of projection steel pipe pile (14).

Next, the cylindrical expanded diameter region of the soil cement composite pile will be explained.

The diameter $Dst_2$ of bottom end enlarged pipe region (14b) of projection steel pipe pile (14) is taken to be

$$Dst_2 \leq Dso_1 \qquad \ldots (c)$$

By satisfying the condition of the formula (c) above, the insertion of bottom end enlarged pipe region (14b) of projection steel pipe pile (14) becomes possible.

Next, the diameter $Dso_2$ of the pile bottom end expanded diameter region (13b) of soil cement column (13) is determined as follows.

First, the case in which pulling force operates is considered.

As shown in Figure 9, if at this time the peripheral frictional strength per unit area between pile bottom end expanded diameter region (13b) of soil cement column (13) and support layer (12) is taken to be $S_3$, the peripheral frictional strength per unit area between the pile front end expanded diameter region (13b) of soil cement column (13) and the bottom end enlarged pipe region (14b) or the front end enlarged plate region (24b) of projection steel pipe pile (14) is taken to be $S_4$, the bond area of the pile bottom end expanded diameter region (13b) of soil cement column (13) and the front end enlarged plate region (24b) of projection steel pipe pile (14) is taken to be $A_4$, and the bearing force is taken to be $Fb_1$, then diameter $Dso_2$ of expanded bottom region (8b) is determined in the following manner:

$$\pi \times Dso_2 \times S_3 \times d_2 + Fb_1 \leq A_4 \times S_4 \qquad \ldots (2)$$

As for $Fb_1$, cases in which the soil cement region is destroyed and the earth of the upper region is destroyed can be considered, but as shown in Figure 9, $Fb_1$ can be expressed with the following formula as a shear fracturing force:

$$Fb_1 = \frac{(Qu \times 2) \times (Dso_2 - Dso_1)}{2} \times \frac{\sqrt{2} \times \pi \times (Dso_2 + Dso_1)}{2} \qquad \ldots (3)$$

At this time, the layer that becomes the support layer (12) of soil cement composite pile (18) is either sand or gravel. Therefore, in pile bottom end expanded diameter region (13b) of soil cement column (13), the strength of the soil cement that becomes concrete mortar is large, and strength greater than the order of uniaxial compressive strength Qu $\fallingdotseq$ 100 kg/cm$^2$ can be expected.

Here, Qu $\fallingdotseq$ 100 kg/cm$^2$, $Dso_1$ = 1.0 m, length $d_1$ of the bottom end enlarged pipe region (14b) of projection steel pipe pile (14) is taken to be 2.0 m, length $d_2$ of pile bottom end expanded diameter region (13b) of soil cement column (13) is taken to be 2.5 m, and if $0.5\ N \leq 20$ t/m$^2$ when support layer (12) is sandy soil from the highway bridge specification, then $S_3 = 20$ t/m$^2$ and $S_4 = 0.4 \times Qu = 400$ t/m$^2$ from experimental results. When $A_4$ is the bottom end enlarged pipe region (14b) of projection steel pipe pile (14), if $Dso_1$ = 1.0 m and $d_1$ = 2.0 m, then:

$$A_4 = \pi \times Dso_1 \times d_1 = 3.14 \times 1.0\ \text{m} \times 2.0 = 6.28\ \text{m}^2.$$

Substituting these values into the aforementioned formula (2), and further substituting them into formula (3),

if $Dst_1 = Dso_1 \cdot S_2/S_1$, then
$Dst_2 \fallingdotseq 2.2$ m.

Next, the case in which pressing force operates is considered.

As shown in Figure 10, if at this time the peripheral frictional strength per unit area between pile bottom end expanded diameter region (13b) of soil cement column (13) and the support layer (12) is taken to be $S_3$, the peripheral frictional strength per unit area of pile bottom expanded diameter region (13b) of soil cement column (13) and bottom end enlarged pipe region (14b) or bottom end enlarged plate region (24b) of projection steel pipe pile (14) is taken to be $S_4$, the bond area of pile bottom expanded diameter region (13b) of soil cement column (13) and bottom end enlarged pipe region (14b) or bottom end enlarged plate region (24b) of projection steel pipe pile (14) is taken to be $A_4$, and the bearing force is taken to be $fb_2$, then the diameter $Dso_2$ of bottom expanded diameter region (13b) of soil cement column (13) is determined in the following manner:

$$\pi \times Dso_2 \times S_3 \times d_2 + fb_2 \times \pi \times (Dso_2/2)^2 \leq A_4 \times S_4 \qquad \ldots (4)$$

At this time, the layer that becomes the support layer (12) of soil cement composite pile (18) is either sand or gravel. Therefore, in pile bottom end expanded diameter region (13b) of soil cement column (13), the strength of the soil cement that becomes concrete mortar is large, and the uniaxial compressive strength Qu can be expected to be approximately 1000 kg/cm$^2$.

Here, Qu $\fallingdotseq$ 100 kg/cm$^2$, $Dso_1$ = 1.0 m, $d_1$ = 2.0 m, and $d_2$ = 2.5 m;
$fb_2 = 20$ t/m$^2$ when support layer (12) is sandy soil from the highway bridge specification;
$S_3 = 20$ t/m$^2$ if $0.5\ N \leq 20$ t/m$^2$ from the highway bridge specification;
$S_4 \fallingdotseq 0.4 \times Qu \fallingdotseq 400$ t/m$^2$ from experimental results;
and when $A_4$ is the bottom end enlarged pipe region (14b) of projection steel pipe pile (14),

if $Dso_1$ = 1.0 m and $d_1$ = 2.0 m, then
$A_4 = \pi \times Dso_1 \times d_1 = 3.14 \times 1.0\ \text{m} \times 2.0 = 6.28\ \text{m}^2$.

Substituting these values into formula (4) described above,

if $Dst_2 \leq Dso1$, then
$Dso_2 \fallingdotseq 2.1$m.

Accordingly, as for diameter $Dso_2$ of pile bottom end expanded diameter region (14a) of soil cement column (13), $Dso_2$ that is determined by pulling force becomes approximately 2.2 m, and $Dso_2$ that is determined by pressing force becomes approximately 2.1m.

Finally, the tensile resistance of the soil cement composite pile of this invention will be compared with the tensile resistance of the conventional expanded bottom cast-in-place pile.

With regard to the conventional expanded bottom cast-in-place pile, if the axis diameter of shank (8a) of cast-in-place pile (8) is taken to be 1000 mm and the tensile resistance of the shank when the bar arrangement quantity is set to 0.8% is calculated for the a-a line cross section of Figure 12 of shank (8a), then the reinforcement bar quantity is:

$$\frac{100^2}{4}\pi \times \frac{0.8}{100} = 62.83 \text{ cm}^2$$

If the tensile resistance of the reinforcement bars is taken to be 3000 kg/cm$^2$, then the tensile resistance of the shank is 62.83 × 3000 ≒ 188.5 tons.

Here, the reason that the tensile resistance of the shank is taken to be the tensile resistance of the reinforcement bars is that concrete cannot rely on tensile resistance, so cast-in-place pile (8) is supported by reinforcement bars alone if it is reinforced concrete.

Next, with regard to the soil cement composite pile of this invention, if the shank of the pile general region (13a) of soil cement column (13) is taken to be 1000 mm, the bore diameter of main body region (14a) of projection steel pipe pile (14) is taken to be 300 mm, and the thickness is taken to be 19 mm, then the steel pipe cross sectional area is 461.2 cm$^2$.

If the tensile resistance of the steel pipe is taken to be 2400 kg/cm$^2$, then the tensile strength of main body region (14a) of projection steel pipe pile (14) is 466.2 × 2400 ≒ 1118.9 tons.

Accordingly, this becomes approximately six times the coaxial diameter expanded bottom cast-in-place pile. Therefore, in comparison to the conventional examples, it has become possible with the soil cement composite pile of this invention to establish large resistance with respect to pulling force by establishing a bottom end enlarged region on the bottom end of the projection steel pipe pile and increasing the bond strength between the soil cement column and the steel pipe pile.

(Effects of the Invention)
As explained above, this invention forms a soil cement composite pile that comprises (a) a soil cement column that is formed under the foundation, the bottom end having an expanded diameter, and has a pile bottom end expanded diameter region of prescribed length, and (b) a projection steel pipe pile that is pressed into the soil cement column before hardening, and has a bottom end enlarged region of prescribed length on the bottom end [sic] that is united with the soil cement column after hardening. Therefore, because a soil cement construction method is employed at the time of construction, it has a low noise level, low vibration, and little waste. Furthermore, because it uses a steel pipe pile, the tensile resistance is improved in comparison to the conventional expanded bottom cast-in-place pile. In step with the improvement of tensile resistance, the bond strength between the soil cement column and the steel pipe pile is increased by establishing a bottom end enlarged region on the bottom end of the projection steel pipe pile and increasing the periphery area with the bottom end, so there is also the effect that the projection steel pipe pile will not escape from the soil cement column and it has large resistance with respect to pulling force.

Moreover, because a projection steel pipe pile is used, the bond adherence with respect to the soil cement column increases, so there is also the effect that the resistance therefore becomes large with respect to both pulling force and pressing force.

Furthermore, optimal pile construction is possible with respect to each of the loads by modifying the diameters of lengths of the pile bottom end expanded diameter region of the soil cement column or the bottom end enlarged region of the projection steel pipe pile according to the sizes of the pulling force and the pressing force, so there is also the effect that economical piles can be constructed.

4. Brief Description of the Drawings

Figure 1 is a cross sectional diagram that shows one example of embodiment of this invention; Figures 2 (a) through (d) are cross sectional diagrams that show the construction process of the soil cement composite pile; Figure 3 is a cross sectional diagram that shows a projection steel pipe pile to which expansion wing bits are mounted; Figure 4 is a cross sectional diagram that shows the main body region and the bottom end enlarged region of the projection steel pipe pile; Figure 5 is a plan view that shows the main body region and the front end enlarged pipe region of this projection steel pipe pile; Figure 6 is a cross sectional diagram that shows an example of variation of the projection steel pipe pile; Figure 7 is a plan view of the example of variation of the projection steel pipe pile shown in Figure 6; Figure 8 is an explanatory diagram for the purpose of securing the foundation bearing capacity of the soft layer; Figure 9 is an explanatory diagram for the purpose of securing the foundation bearing capacity of the support layer with respect to pulling force; Figure 10 is an explanatory diagram for the purpose of securing the foundation bearing capacity of the support layer with respect to pressing force; Figure 11 is an explanatory diagram that shows a steel tower created through the conventional earth anchor construction method; and Figure 12 is a cross sectional diagram that shows the conventional expanded bottom cast-in-place pile.

(10) is the foundation, (11) is the soft layer, (12) is the support layer, (13) is the soil cement column, (13a) is the pile general region, (13b) is the pile bottom end expanded diameter region, (14) is the projection steel pipe pile, (14a) is the main body, (14b) is the bottom end enlarged pipe region, and (18) is the soil cement composite pile.

Agent Muneharu Sasaki, Patent Attorney

[see source for figures]

Figure 1

10: Foundation
11: Soft layer
12: Support layer
13: Soil cement column
13a: Pile general region
13b: Pile bottom end expanded diameter region
14: Projection steel pipe pile
14a: Main body
14b: Bottom end enlarged pipe region
18: Soil cement composite pile

Agent Patent Attorney Muneharu Sasaki

Figure 2

Figure 3

Figure 4

Figure 6

Figure 5

Figure 7

Figure 8

Figure 9
Pulling Force

Figure 10
Pressing Force

Figure 11

Figure 12

Continued from the first page

(72) Inventor: Tetsuzou Hirose c/o NKK Corporation
1-1-2 Marunouchi, Chiyoda-ku, Tokyo

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Kim Stewart

Kim Stewart
TransPerfect Translations, Inc.
3600 One Houston Center
1221 McKinney
Houston, TX 77010

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